Marked-Up Copy of Specification

SYSTEM FOR FINGERPRINT AUTHENTICATION [[,]] BASED ON RIDGE SHAPE

INFORMATION

BACKGROUND OF THE INVENTION

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Field of the Invention

The present invention relates to a system for fingerprint authentication, which is

provided to extract minutia ridge shapes by use of using simple data format to recognize

10   curves and [[is]] to provide fast and effective mechanism with less memory space and

computation complexity. Moreover, the invention achieves a higher identification

precision for the poor quality fingerprints by use of secondary minutia, false minutia

detection, treatment of shifted and rotated fingerprint input, pipeline parallel processing

within 0.24 seconds for raster scan image capture and feature extraction processing. The

15   invention is used with computer, or any kind of processor or dedicated LSI (Large scale

integrated circuits).

Description of the Prior Art

One type of prior art fingerprint authentication systems is to extract position of

~~minutia~~ minutiae, which are points of ridge endings and bifurcations, in fingerprint images

5   for both templates and an input sample. Matching or verification is performed between

extracted data of input sample and template. Since fingerprint images of the input sample

and template differ in their position, rotation angle and noise environment, matching

operation has large computational complexity such as compensation of shifting and

rotation, and false minutia elimination. Main reason for difficulties in prior art comes from

10   adoption of absolute measure, such as position of minutia, which is sensitive against

shifting, rotation and noise.

SUMMARY OF THE INVENTION

15   The present invention is directed to a curve recognition system and its application

to fingerprint authentication based on ridge shape information. [[It is]] The system of the

present invention uses small size data format for curves on discrete grids, and relative

measure robust against shifting, rotation and noise. The invention provides fast and

accurate fingerprint authentication algorithm and hardware system with small data

storages of 50 bytes. Several important techniques are included in the invention such as

secondary minutia, criteria for true or false minutia, treatment of shifted and rotated

fingerprint input, pipeline parallel processing within 0.24 seconds for raster scan image

5   capture and feature extraction processing, and several useful applications such as on-line

verification.

BRIEF DESCRIPTION OF THE DRAWINGS

10   Figure 1 illustrates to derive derivation of numerical data to express information of

minutia ridge shape[[.]];

Figure 2 illustrates the movement and rotation of the image to be recognized;

Figure 3 illustrates the principle to calculate approximately of calculating

approximate coordinates of measure points, which locates located between pixels grids;

15   Figure 4 illustrates another feature data to express minutia ridge shape[[.]];

Figure 5 illustrates an algorithm to extract true minutia by thinning operation and

reverse operation between black and white over black and white binary image[[.]];

Figure 6 illustrates algorithm for extraction of true minutia including improvement of gray scale image[[.]];

Figure 7 illustrates false minutia, which consists of:

(a) two ending minutia close to each other, which posses the same directions as

5   their minutia ridge shapes[[.]];

(b) an ending minutia near a bifurcation point[[.]];

(c) an ending minutia near boundary of image[[.]];

Figure 8 illustrates process of both reverse of black and white and thinning[[.]];

Figure 9 is an example [[for]] of describing [[the]] a secondary minutia in

10   associated with a minutia[[.]];

Figure 10 is an example to detect of detecting a false bifurcation minutia [[in]]

according to this invention[[.]];

Figure 11 represents [[2]] two-dimensional memory areas of M rows and L

columns for manufacturing without compensation for displacement.;

15   Figure 12 illustrates algorithm of feature extraction for a curve recognition system

by use of raster scan image capture[[.]];

Figure 13 illustrates an exemplary embodiment of an algorithm for finger

authentication system as an example of this invention.

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DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 illustrates ~~to derive~~ derivation of numerical data to express information

of minutia ridge shape. Minutia is a special point on ~~the~~ a ridge of fingerprints, whether

5   the ridge is terminated at the point or ridge is bifurcated at the point. The former minutia is

called an ending minutia, while the ~~latte~~ latter is called a bifurcation minutia. Minutia

ridge is a ridge ~~leaving~~ departing from any kinds of minutia. Consider a minutia ridge,

which is smooth curve, or ridge, 40 leaving from a minutia 30 as shown in Figure 1.

Sampling points (called measure points, hereafter) 31, 32, 33 and 34 on the ridge

10   are taken in such a way that ~~ares~~ chords 41, 42, 43 and 44 between measure points become

unit lengths. This is in a way similar ~~way~~ to ~~measure~~ measuring ~~path on the curve~~ a length

of a curve in ~~the~~ a map by use of a divider.

Based on ~~said ares~~ the chords, a length of ~~are~~ a chord 51 is measured as a feature,

which becomes ~~an are~~ a chord of a triangle comprised by the first and the second measure

15   points 31 and 32, and the minutia 30.

Actually, the measure points 31, 32 and 33 are decided by measuring unit length

from previous measure point along the ridge 40, one by one. The length of ~~are~~ the chord

from each measure point to its ~~second~~ next measure point is measured. As an example, ~~are~~

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the chord [[52]] 51 from the minutia 30 to its the second next measure point 32 is

measured, and are the chord [[53]] 52 from the first measure point 31 to it's the third

second next measure point 33 is measured, and the chord 53 from the second measure

point 32 to the fourth measure point 34 is also measured.

5   As a result of this measurement, the numerical length data of ares the chords 51,

52 and 53 are used as information to express the minutia curve shape of the curve 40.

These simple numerical data become fingerprint feature data.

By use of matching these fingerprint feature data with content of database (called

template, hereafter) registered in advance, the system achieves fast matching and high

10   recognition rate with a few memory in data size.

Consider the input fingerprint image, in which the curve 40 moves and rotates as

shown in Figure 2. If shape of the curve 40 is expressed by said the numerical data such as

lengths of are the chords 51, 52 and 53, they do not change against any move and any

rotation of the curve 40. Therefore, said the numerical data such as the lengths of the

15   chords 51, 52 and 53 can be recognized, stored, regenerated recognize, store, regenerate

and distinguish shape of the curve 40 from an original curve. Matching or verification of

shape of curve can be detected by comparing those numerical data.

Figure 3 illustrates the principle ~~to calculate~~ of calculating approximate

~~approximately~~ coordinates of measure points, ~~which locates~~ located in a grid ~~between~~

~~grids~~. The grid is in the form of an array of pixels in a digital ~~The~~ image captured by

digital camera or video deck. The grid is comprised ~~precisely~~ by a certain number of the

5   pixels, which react to the light ~~in similar~~ similarly to retina of human eyes. ~~Though said~~

The pixels ~~look precise textile, they~~ are placed regularly with a certain period over the

rectangular grid ~~grids~~.

In the case of digital image processing on computers, image data are represented

by values on the pixels, which lie over rectangular grids as shown in Figure 3. Among

10   those pixels, ~~colored~~ tinted pixels are one to represent a curve.

Therefore, a measure point 12, which is expected to be 4 pixels far from a

standard pixel 100 on the curve, may not be on an actual pixel. In this case, location of the

measure point 12 must be calculated by location of 2 pixels 10 and 11 on the curve, which

are the closest pixels to the measure point 12 and [[of]] 4 pixels far from the pixel 100. As

15   an example, location of the measure point is calculated by the simple linear interpolation

between the location of a first pixel 10 and location of a second pixel 11. In this way,

lengths of ~~arcs~~ the chords 51, 52 and 53 are obtained by using the measure point 12, whose

location is not different from location of the pixels.

The present invention includes an algorithm to calculate the measure point 12 on

the curve 40, which locates is located a specified distance from a point on the curve 40.

This algorithm enables to deal with images of infinite resolution theoretically, if the

location between two pixels is calculated in the image field of a finite resolution.

5   Consider a triangle[[,]] consisting of a standard point pixel and 2 closest pixels 10

and 11 on the curve, which are direct distance 99 far or close pixel from the standard

point, respectively. Let an are a chord between the standard point pixel 100 and the first

pixel 10 denote the a first are chord. Let an are a chord between the standard point pixel

100 and the second pixel 11 denote the a second are chord. Furthermore, let an are a chord

10   between the first are pixel 10 and the second are pixel 11 denote the a third are chord.

Then, a measure point on the third are chord is decided in such a way that the point divides

length of the third are chord at the same ratio of lengths between the first and second are

chord. This interpolation increases the capability of curve recognition to large extent,

regardless of the precision of this approximation.

15   Figure 4 illustrates another feature data to express minutia ridge shape. Let's

consider a minutia curve or ridge shape (400), which extends to reverse direction to

bifurcation as shown in Figure 4. Let a point on the ridge (400) denote "the second

measure point" (402), which locates a distance D far from the first measure point (401). In

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similar way, we measure the 3rd measure point (403), which locates the distance D farther

than the second measure point. Then, we measure the 4th and 5th measure point (404) and

(405), respectively. This procedure can be repeated until the ridge terminates or goes

outside of boundary of image. Then, a series of ~~arcs~~ chords between adjacent measure

5   points approximates shape of the curve (400).

An [[A]] effective method to express this piece-wise linear curve is to measure

"directional angle", which is defined or calculated by an angle between standard axis and

line connected from minutia (401) to the 1st measure point. Then, "the first curvature" is

measured, which is defined or calculated by an angle between line connected from minutia

10   (1) to the 2nd measure point (402) and line connected from the 2nd measure point (402) to

the 3rd measure point (403). Similarly, "the second curvature" is measured, which is

defined or calculated by an angle between line connected from the 2nd measure point (402)

to the 3rd measure point (403) and line connected from the 3rd measure point (403) and the

4th measure point (404). In this way, angles are measured between adjacent lines, which

15   are connected between measure points along the ridge. Thus, the necessary information

becomes a directional angle of minutia (408) and group of ~~curvatures~~ curvature angles

between adjacent lines (409), (410), (411).

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Since the directional angle and group of ~~curvatures~~ <u>curvature angles</u> express well

a ridge shape, the capability of curve recognition is greatly improved by use of the

information. This expression can be applied ~~to~~ not only <u>to</u> bifurcation minutia, but <u>also to</u>

<u>the</u> ending minutia.

5   Figure 5 illustrates <u>an algorithm</u> to extract true minutia by thinning operation and

reverse operation between black and white over black and white binary image. The

original black and white image is processed by cascade connection of thinning block (Step

S7) and compensation block of false minutia (Step S8).

The contour along ridge of black object in black and white image is reduced to 1

10   pixel in width. Thinning is <u>a</u> conversion from <u>an</u> area to <u>a</u> line as shown in Step S7. More

detail thinning process is described later according to Figure 8.

The first extraction of <u>the</u> ending minutia in original black and white image, black

and white reversal process (Step S70) and the second cascade processing over reversal

image, and the second extraction of ending minutia in reversal image can be performed

15   without extracting both ending and bifurcation minutia. This is also described in detail

according to Figure 8.

This ~~scheme~~ process makes the algorithm more suitable, faster and more accurate

to treat huge number of templates and samples without using large memory area and with

simple hardware.

Figure 6 illustrates an algorithm for extraction of true minutia including

5   improvement of gray scale image. Contrast of a block, partitioned by block partitioning, is

enhanced until it becomes binary image of black and white. This is the first binarization

step. Then, a ridge direction is calculated by ridge direction detection.

This ridge direction is used as a secondary information in eliminating noise

component. Image information along ridge direction is judged as a valid information of

10   ridge, while image information not along ridge direction is considered as a noise. This

process is called as improvement of gray scale image.

Here, Binarization is ~~originally a process for analog signal to be digitalized, Here,~~

~~this term is used as~~ a process to convert 8 bit gray scale data into 2 bit black and white

data.

15   Figure 7 illustrates a false minutia, which consists of:

(a)   two ending ~~minutia~~ minutiae (20) close to each other, which posses the

same directions as their minutia ridge shapes[[.]];

(b)   an ending minutia (21) near a bifurcation point[[.]]; and

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    (c)   an ending minutia (22) near boundary of image.

After false minutia elimination (Step S8), which compensates noise components in

~~said~~ the fingerprint data, the next procedure ~~goes to~~ is extraction of true minutia (Step S9).

~~Detail~~ Details of the true minutia extraction (Step S9 [[8]]) [[is]] are explained as a post

5   processing according to Figure 7.

Figure 7 (a)(b)(c) illustrates 3 kinds of the false minutia described ~~as~~ above, which

are falsely recognized as the true minutia. Compensation rule for the false minutia is

adopted as a post processing, which adds a ridge to connect two ending ~~minutia~~ minutiae

close to each other with the same direction or an ending minutia close to bifurcation point,

10   or an ending minutia close to boundary of image.

Referring to Figure 6 again, contrast of ~~said~~ the improved image is enhanced up to

obtain binarized image (Step S6). This binary image is derived from compressing width

towards the center in thinning process (Step S7).

Thinning process (Step S7) brings an additional effect on simplifying complicated

15   verification process.

~~At next~~ Next, the false minutia compensation (Step S8) is performed, which adds

the ridge to connect two ending ~~minutia~~ minutiae 20 close to each other with the same

direction, or an ending minutia 21 [[22]] close to bifurcation point, or an ending minutia

12

22 near the boundary of the image.

In this way, true minutia extraction (Step S9) extracts remaining ending and

bifurcation points as true minutia, after an above sequence of processing is applied over

the input image, including compensation of the false minutia. The fingerprint verification

5   based on this method reveals high verification rate for noisy input images.

Figure 8 illustrates process of both reverse of black and white and thinning. In

Figure 8, (a) corresponds to black and white picture before processing[[.]]; (b) corresponds

to intermediate result for minutia extraction[[.]]; (c) corresponds to black and white

reverse (or inverted) image[[.]]; and (d) corresponds to extracted minutia after the final

10   processing.

The true minutia extraction with thinning (Step S7) and reverse reversal of black

and white image (S70) was explained by using Figure 5. Though great reduction of image

information is achieved, there still remains difficulty to digitalize bifurcation points.

Similarly, great reduction of information is achieved as shown in Figure 8(b) and

15   Figure 8(a). However, there still remains remain critical problems, to which a unique judge

judgment can not be applied.

Therefore, in order not to deal with bifurcation minutia, the processing as shown

in Figure 8 (a) to (c) is performed over reverse black and white image (Step S70). Then,

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thinning process (Step S7) as shown in Figure 8 (c) and (d) leads to ending of finite curve,

i.e., the ending minutia instead of ~~said~~ the bifurcation. This processing is repeated twice.

In such a way, the finite curves are extracted, which do not include any

bifurcation or any intersection of rides. This scheme reduces amount of necessary

5   information to express fingerprint, and thus, makes numerical expression easy. The

numerical information becomes quite small in comparison with the original image.

In this way, fingerprint verification can be uniquely performed. Since no ~~judge~~

judgment of a human being is required, fast processing with small memory capacity and

small load for database ~~become~~ becomes possible.

10   Figure 9 is an example for describing ~~the~~ a secondary minutia in associated with

[[a]] an original minutia (91). According to direction of minutia ridge, vertical axis (Y1) is

set. Consequently, horizontal axis (X1[[2]]) is ~~decided~~ determined as shown in Figure 9.

The four points (92), (93), (94) and (95) are determined on the ~~axis~~ axes in such a way that

the distances between these 4 points and the original minutia (91) are equal ~~the same~~.

15   The ridge shapes (RS1), (RS2), (RS3) and (RS4) leaving from the nearest point

on the ridge (herein, called as "secondary minutia") to those four points are extracted by

use of ~~said~~ the curve recognition method, respectively. These ridge shapes are additional

information in associated with the original minutia (91) to express features of fingerprint.

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The fingerprint authentication system with ridge shapes of the secondary minutia brings

the tremendous improvement on precision of matching.

Figure 10 is an example of detecting to detect a false bifurcation minutia in this

invention. True bifurcation minutia in most cases partitions the fingerprint area into 3 parts,

5   which consists of one narrow acute angular area (less than 90°) (A101) and two wide

obtuse angular areas (more than 90°) (A102) and (A103). The same things can be said for

bifurcation minutia in valley. Bifurcation minutia in valley [[in]] is associated with the

ending minutia partitions the fingerprint area into similar 3 parts of 1 narrow acute angular

area and 2 wide obtuse angular areas.

10   This characteristic is used to judge whether a detected minutia is true or false. For

this purpose, 3 points on each ridge or each valley line are selected in such a way that they

are the same distance far from the bifurcation minutia. Let 3 points denote as points (102),

(103) and (104), whose coordinates are (Xa, Ya), (Xb, Yb) and (Xc, Yc) respectively in

coordinate system of an origin point (101).

15   With regards to a point pair of point points (102) and point (103), we calculate the

sum (XaXb+YaYb) of product (XaXb) of horizontal coordinate pair and product (YaYb)

of vertical coordinate pair of the two points. Herein, the sum (XaXb+YaYb) is called as

"an inner product of 2 points". The value of this inner product corresponds to cosine

function of the angle between a line of (101)-(102) and a line of (101)-(103). It means that

if the cosine value is ~~large~~ positive, the angle between the two lines is ~~narrow~~ acute (less

than 90°) and if ~~otherwise~~ the cosine value is negative, the angle between the two lines is

~~wide~~ obtuse (more than 90°). In similar way, an inner product of two line pair of (101)-

5   (103) and (101)-(104), and an inner product of two line pair of (101)-(102) and (101)-

(104) are calculated.

The point (101) is judged as a true minutia if there exists only 1 ~~greater~~ positive

inner product among these 3 inner products. This case corresponds to the situation of true

bifurcation minutia, where only one ~~narrow~~ acute angular area exists. Otherwise, the point

10   (101) is judged as a false minutia.

Even if two fingerprint images of ~~identical~~ the same finger are captured by the

system, positions and directions of extracted minutia are not the same. They depend on the

~~positions~~ position and ~~angles~~ angle of the finger put on an input sensor. For matching

between two fingerprint images, one of the images should be compensated before

15   comparison in the conventional method. To specify displacement and rotation and to

compensate them ~~need~~ tremendous amount of computation is deeded. In order to avoid

this difficulty, ~~it is~~ usually ~~that~~ displacement and rotation of input fingerprint image are

strictly restricted. The present invention presents the matching method without

compensation for displacement due to simple shifting.

Figure 11 represents 2-dimensional memory areas of M rows and L columns.

Before the process of fingerprint matching, the memory areas are supposed to have some

initial values such as zero.

5   Here, consider a similarity measure of any kinds, whose numerical values

correspond to how similar any pair of ~~minutia~~ minutiae in two fingerprint images is. This

similarity measure is calculated based on the ridge direction and a similarity of curve

shape. If pair of ~~minutia~~ minutiae is quite similar, a value of similarity function becomes

large. On the other hand, if pair of ~~minutia~~ minutiae is not so similar, a value of the

10   similarity function becomes small.

For ~~said~~ those two ~~minutia~~ minutiae, ~~let~~ (Xa, Ya) and (Xb, Yb) denote 2-

dimensional coordinates in two fingerprint images, respectively. 2-dimensional vector

(Xb-Xa, Yb-Ya) is a vector from the position of the minutia in one fingerprint image to the

position of the minutia in the other fingerprint image. This means that the minutia shifted

15   with (Xb-Xa) along horizontal direction and (Yb-Ya) along vertical direction if the former

minutia matches with the latter one. If the value of similarity function between two

minutia is large, the possibility of displacement (Xb-Xa, Yb-Ya) of the former fingerprint

image is high. On the contrary, if the value of similarity function between two minutia in

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different fingerprint images is small, the possibility of displacement (Xb-Xa, Yb-Ya) of the

former fingerprint image is small.

After a comparison between two ~~minutia~~ minutiae in different fingerprint images,

the value of similarity measure is added to the value, which is stored in memory area of

5   (Xb-Xa, Yb-Ya) corresponding to ~~said~~ the 2-dimensional vector (Xb-Xa, Yb-Ya). A

sequence of operations is repeated for comparison between each minutia pair in different

fingerprint images.

As a result, the values in the memory distribute over different addresses because

of inaccuracy of position estimation of the extracted minutia. If minutia positions are

10   accurately extracted, the strong peak value can be expected in the memory. On the

contrary, in case two ~~minutia~~ minutiae are produced by the different fingers, the same

operation may bring the distribution of values in memory without any large peak value.

However, since to specify amount of displacement is not a final purpose, the

maximum value in memory is directly evaluated. If it exceeds a certain threshold value,

15   two input fingerprints are concluded to be identical. Otherwise, two input fingerprints are

likely to be different.

The present invention gives a solution not only for shifting, but for rotation of

fingerprint images by use of ~~said~~ the matching method without using any compensation of

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shifting. To compensate displacement due to rotation, all the ~~minutia~~ minutiae of the input

fingerprint image are compensated for rotation. ~~Remind~~ It should be reminded that feature

data in the present invention consists of 2-dimensional coordinates and the information for

minutia ridge shape. The 2-dimensional coordinates or position of minutia are

5   compensated by rotation around a standard origin point with a certain angle. Among

information for minutia ridge shape, directional angle of minutia is also compensated to

the same extent. However, compensation is not necessary for curvatures of minutia ridges

because they are invariant against rotation. After compensating all minutia ridge shapes

with the angle, the method without compensation of shifting is applied to do matching

10   between two fingerprint images.

Since rotation angle is not known, the above processing is repeated for different

~~angle~~ angles of rotation until a rotation angle is specified by getting the largest values in

memory.

Figure 12 illustrates algorithm of feature extraction for recognition system by use

15   of raster scan image capture. Camera image capture, which is similar to raster scan TV set,

sends one frame data in a certain period of time to a Digital Signal Processor (hereafter,

called as DSP). Camera scans sequence of frames at a certain frame rate such as 25 or 30

frames per second. In each frame, a block data of partial area in a frame is stored (Step

S92). Then, feature extraction processing (Step S93) is performed in limited short time

as shown in Figure 5 and 6.

Feature extraction processing (Step S93) is performed by a computer, which

executes 1 million instructions per second. Assuming that fingerprint feature data of 50

5 bytes is assigned to the computer, it takes about 0.24 second for feature extraction (Step

S93) and ~~their storages~~ its storage (Step S94). ~~This~~ The verification time corresponds to

time for 6 or 7 ~~frame~~ frames in raster scan system of 25 or 30 frames per second.

Actually, consecutive 5, 6 or 7 frames are required under the assumption that

input fingerprint images are identical among those frames. Feature extraction (Step S93)

10 and storage of feature data (Step S94) for whole fingerprint image completes within raster

scan time for 5, 6 or 7 frames. Then, termination of whole image processing (Step S95)

~~also terminates~~ concludes the algorithm.

Figure 13 illustrates an algorithm for finger authentication system as an exemplary

embodiment ~~example~~ of this invention.

15 Processing from camera image input (Step S1) to true minutia extraction (Step

S9) and then termination of whole image processing (Step S95) consists of partial

algorithms explained with the reference to Figures ~~Figure~~ 5, 6, 7, 8 and 9.

Block thinning (Step S2) after camera image input (Step S1) is always necessary

in actual implementation, which leads to binarization (Step S3) and improvement of gray

scale image (S5) for each partitioned block image.

When the result of the termination step of the whole image processing is "YES",

the next step becomes either matching process (Step S74) or storage in the database of

5   fingerprints (Step S75). In matching process (Step S74), the extracted feature data in the

form of numerical data is used to compare with templates stored in the database of

fingerprints.

In block processing, blocking noise is usually generated, which is seen as

discontinuity of images on the boundary of blocks. The noise is eliminated by computer

10   software. In order not to lose necessary information and to keep or capture information of

whole image, boundary data of blocks overlap with data in adjacent blocks.

In this way, computer with ability of 1 million instructions per second[[,]]

performs a sequence of processing steps such as noise elimination of input fingerprint

image, image improvement, binarization, thinning, elimination of false minutia and

15   matching with database[[,]] within 0.24 seconds by use of from 40 to 60 bytes data for the

extracted features.

Herein, improvement and various kinds of processing are explained in detail.

Ridge direction is extracted from the fingerprint image before partitioning into blocks as

shown in Figure 6 and Figure 13. Then, a directional filter, not shown in the figure, is used

for ~~said~~ the improvement of gray scale image (Step S5). When the fingerprint image is

input to the directional filter, it is modified if a part of image is quite different from the

ridge shape of the normal fingerprint. Modification is performed by computer, but it

5   resembles such a human's action that contour of the ridge is redrawn by hand to make

ridge image clearer.

Sophisticate software is implemented on the ~~Digital Signal Processor (hereafter,~~

~~called as~~ DSP[[)]]. It is quite similar to such human's action ~~that~~ where the parts to be

modified are detected by eyes and modified by hand based on estimation derived from the

10   ridge direction information around them.

Block thinning is a processing of each block, obtained by partitioning the raster

scanned whole image into a rectangular array. It leads to unique processing by simplifying

complex image processing, which is not suitable for computers. If width of a ridge is

reduced to one pixel in size, the minutia ridge shape becomes a simple line connected to

15   the minutia. It enables machine recognition with unique processing.

For those processing, the whole information for ~~said~~ the block image is not stored

in memory at [[a]] the time. The ~~Local~~ local minutia 30, which [[are]] is resistant ~~robust~~

against rotation, shifting and noise, and their associated ~~ares~~ chords 51, 52, 53, are

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extracted by local processing soon after block image is read[[.]], ~~While~~ while[[,]] the other

raster scanned block images are not read during processing of the block. This ~~scheme~~

process reduces required memory capacity.

Actual system configuration consists of a compact video camera and the ~~Digital~~

5   ~~Signal Processor~~ (DSP[[)]]. Algorithm in this invention is stored as program in the DSP.

The 32 x 22 pixel image in each small block is selected from 200 x 200 =40,000

pixels, which are a whole image input from the video camera in raster scan fashion. They

are stored temporary in data memory of the DSP. By the described processing, information

of minutia ridge shape is extracted as a numerical data[[,]] based on the measure points 31,

10   32, 33, and 34 on the ridge 40.

Next, an input data of another block image is processed in the same way. Since it

takes time to extract ~~ares~~ chords 51, 52, 53 as feature data, consecutive block image is not

processed in the same frame. Since computer is busy to extract the minutia ridge shape

information, it does not accept new input information during processing so as to save

15   memory capacity.

Since each block processing can be performed independently [[on]] of each other,

6 frames are input to cover whole image area under raster scan speed of 25 frame per

second (corresponding to PAL or SECAM in Europe and Russia). In other words, a little

bit more than 1/6 image data of each frame is input to the computer. Described overlapped

image between adjacent blocks makes data size of each frame greater than 1/6 image data.

Since it takes at least about 0.24 seconds for said the DSP to extract said the

minutia ridge shape information, whole image area cannot be covered by 1 frame raster

5   scan input. 1 frame raster scanning takes similar time [[to]] of 1/25 or 1/30 (NTSC in US

and Japan) seconds. Therefore, during time of 6/25 or 7/30 seconds to scan 6 or 7 frames,

consecutive operations, such as capture of the partitioned block image and processing of

the image to final format as feature data, are repeated.

In practical application of the fingerprint authentication system, template data,

10   which are also extracted feature data of fingerprint, are is stored in advance in memory of

the DSP or database in a host computer. Then, the input feature data is extracted as a

sample from the input fingerprint image for verification. The data is matched compared

with several templates registered in the database. By using criteria for verification, the

system judges whether the input fingerprint is accepted or rejected by the system.

15   As a measure to evaluate the fingerprint authentication system, there are two kinds

of measure, which are false acceptance ratio (referring referred to as FAR) and false

rejection ratio (referring referred to as FRR). FAR is a ratio between falsely accepted

samples (unregistered fingerprint) among many samples for verification. Ideal system

requires that the FAR is zero. However, the zero FAR means the complete verification

system, which may reject not only unregistered samples, but some of registered samples.

On the other hand, the FRR is a ratio between falsely rejected samples (registered

fingerprints) among many samples for verification. In practical system, FRR and FAR are

5   closely related with each other. Those values traded off by changing a threshold value,

which is used to judge acceptance or rejection in verification. A score as a similarity

measure is usually generated as a result of matching between input sample and registered

template. If the higher threshold is set, the FAR become becomes smaller, while the FRR

become becomes larger.

10   This invention succeeds to achieve the FRR less than 1.2% when the FAR is set to

be zero. The result is compared with the world top data of 27.72%. This improvement also

means the improvement of recognition ability against rotated, shifted and noisy input

fingerprint images.

Extraction of 50 bytes feature data and verification in this invention is actually

15   implemented on the DSP in speed of 1 million instructions per second. It takes 0.24

seconds for a sequence of processing such as noise elimination, image improvement,

binarization, thinning and verification. This time shows greater improvement than

conventional one in terms of speed and accuracy.

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When this invention is used over networks to connect to an information center,

which stores fingerprint feature templates, the system works as on-line personal

authentication system accessed in remote.

The rule to authenticate registered person by logical operation such as AND,

5   NAND, OR, and NOR of fingerprint feature data of plural fingers. For an example, the

acceptance rule at home may be OR operation among fingerprints of thumbs of father,

mother and all children. For another example, it may also be applicable to authentication

of a car ~~driving~~ driver according to damage insurance for automobile accidents limited to

drivers in family.

10   Since each person has [[20]] 10 fingers, their combinations possess more variety

than encryption. In addition to that, the ability to protect personal rights is increased more

strongly than encryption. If the acceptance rule of AND operation of both thumb and baby

fingers is adopted, its ability ~~become~~ becomes tremendous.

Even if a new law in terms of electronic commerce in United States of America

15   permits "encryption possesses equivalent lawful effect on signature", it is concluded as a

usual and final decision in terms of personal authentication that fingerprint authentication

will keep priority to encryption.

In summary, the present invention provides a curve recognition system and its

application to fingerprint authentication based on ridge shape information, which achieves

small size data format for curves on discrete grids, fast and accurate fingerprint

authentication algorithm and hardware system with small data storages. Several important

techniques are included in the ~~convention~~ <u>system</u> such as ridge shape of secondary points,

5   true and false minutia detection, treatment of shifted and rotated input of fingerprint image,

pipeline parallel processing for raster scan image capture and feature extraction processing,

and several useful applications.

<u>The system for fingerprint authentication of the present invention is used with</u>

<u>terminal or stand-alone equipment, which posses a function such as search for personal</u>

10   <u>history, key lock, issue of various tickets, access control and toll of gates, electric</u>

<u>commerce, and fund management in medical, social welfare, service, public service, and</u>

<u>financial organization. Preferably, the system for fingerprint authentication is embedded in</u>

<u>hardware or software as a part of design data protection. To use the hardware or software</u>

<u>requires personal authentication with fingerprints.</u>

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ABSTRACT OF THE DISCLOSURE

A system [[and]] <u>comprising</u> means, which stores, regenerates, or matches shape

of curves, by using a specified group of data in length to express a shape of curve. ~~They~~

5   ~~use~~ <u>The system uses</u> a sequence of several measure points on the curve, which are

determined so as to make the same distances between those adjacent measure points. They

are the data of lengths of arcs between starting measure point and ending measure points

among every [[3]] <u>three</u> consecutive measure points on the curve.